EVAPORATION AS A SIMPLE INDEX TO WEATHER CONDITIONS.

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The principle upon which the use of evaporimeters has been based, in connection with the study of forest fire weather, is very simple. As, in the continental United States, periods of low barometric pressure are commonly periods of rainfall, so also the intervening periods of higher pressure are usually periods in which drying occurs progressively for several days. A measurement of the rate of evaporation probably expresses, in as simple a term as is possible, the rate at which and the extent to which moisture accumulated in the forest litter during wet periods is being or has been dissipated. Every factor which influences the dryness of the forest floor enters into the evaporation rate as measured instrumentally. Even the time and amount of precipitation can be largely ignored, since so long as the moisture of a rain is retained its presence will reduce locally the evaporation rate.

There is an apparent limitation upon the use of the evaporation rate to show the condition of the forest with respect to dryness. Just as the current humidity fails to show the *extent* to which drying may have proceeded, so also, if a constant evaporation rate is maintained for several days, it must be assumed that a certain degree of dryness in the forest has been attained, and very little additional drying is to be expected. To this extent the cumulative evaporation over a long period has no precise statistical value. However, the fact that two succeeding days seldom show the same evaporation rate is an argument in favor of the use of this measure of weather conditions. The evaporation rate increases and decreases by surges, the average period for a complete cycle being about seven days, and, of course, corresponding to the average period between cyclonic storms. The evaporation curve is not symmetrical, the descent from the peak day being more precipitous than the ascent to the peak. It thus becomes apparent that, owing to the cumulative effect of dissipation of the moisture, the rate of evaporation may increase almost up to the time of occurrence of a rain.

The instrument in use in these studies is the so-called "inner cell wick evaporimeter" designed by the present writer and described in the MONTHLY WEATHER REVIEW for May, 1919. This evaporimeter possesses certain practical advantages which, perhaps, make it more valuable than other atmometers in the hands of inexperienced observers. Among the advantages may be mentioned the fact that it functions satisfactorily in freezing weather, when often the greatest fire hazards exist. The greatest difficulty arising in its use has been the impossibility of maintaining its calibration with reference to a standard instrument. The evaporimeter also has not been entirely freed from the influence of splashing rainfall.

Measurements of the loss by evaporation are made in the morning of each day.

During the season of 1922 a number of these inner cell evaporimeters were in use at scattered points in all of the western districts of the Forest Service. The writer has as yet been unable to learn whether any of the users established a correlation between the recorded evaporation rates and the occurrence of fires.

Since May 1, 1923, the inner cell evaporimeters have been in use at five forest headquarters in district 2, in addition to the regular equipment at the Fremont Experiment Station, near Manitou, Colo. Up to the time of preparation of this paper (August 15), the season has been an unusually moist one, so that very few fires have occurred. It is, therefore, almost too early to attempt to show that the evaporation rate is a valuable index of forest fire conditions. Believing that meteorologists will readily concede its possibilities, the object of the present paper must be to point out certain technical features which have developed in the records of 1923, and which may be of interest largely from the meteorological standpoint.

At the outset it was believed that the absolute rate of evaporation might be used as a direct index of the fire hazard. Realizing that the evaporation rate would ordinarily pass through a low phase and a high phase about every seven days, it was believed that the four days during which the rate was below the average would be practically free of fire hazard, while the three days during which the rate was above average would be the period of great danger. After the record for the first such day had been obtained, it might confidently be expected that the two succeeding days would be days of increasing danger, and preparations could be made accordingly.

The few fire records which can be correlated with the records of evaporation during 1923 show that the matter is not so simple as this, however. While the cycles occur with reasonable regularity, they are dissimilar to teach other. Some low-barometric periods bring soaking rains and bring the evaporation curve to the base line, while other low-pressure periods bring only slight rains and the atmosphere quickly becomes dry again. It appears that the fire hazard is only completely relieved when complete saturation of the atmosphere and of the ground occurs. While it is doubtless true that the hazard is lessened by any degree of moisture or rainfall, still, owing to the large number of factors entering into the fire situation, vigilance can not be relaxed unless the relief has been quite complete.

It will, then, be asked, "In what way is the evaporation record superior to the precipitation record?" It is probably superior only in the sense that it leaves little room for judgment as to whether the country has been effectively soaked. For example, a very heavy but localized rain can not sufficiently moisten the atmosphere to hold the evaporation at zero for a 24-hour period. The evaporation record, also, has its value in the period between rains, in showing the *degree of dryness* which exists. The evaporation figure includes the influence not only of relative humidity, but of temperture, sunlight intensity, and wind movement. We have little doubt but that, with further records, a close relation will be found to exist between both the number and intensity of forest fires and the absolute evaporation rate.

The second point to be observed is the dissimilarity of the evaporation curves for the different stations in the same region. During the season of 1923 evaporimeters have been in use at Grand Junction and Manitou, Colo., at Sheridan and Laramie, Wyo., Custer Peak, S. Dak., and Halsey, Nebr. The first two and the last four stations comprise two west-to-east series, in each of which, it was thought, it might be possible to observe the eastward movement of the cyclonic disturbances which, as a whole, have been the greatest influence on the evaporation rate. The results in this respect have been somewhat disappointing. Neither the 24-hour periods of highest or lowest evaporation at Grand Junction regularly precede the corresponding periods at Fremont, which lies about 170 miles due east. In the Sheridan-Black Hills-Nebraska series the sequence of events appears to be still less regular, although as a general rule the eastward movement can be traced. It appears that both local disturbances and deviations of the cyclonic centers from a regular course inject too many elements of uncertainty to make it practical to forecast the progress of evaporation at any distant point. With the information which is available to the Weather Bureau, it is probable that the rate of evaporation could be forecast, in general terms and for broad regions, as accurately as rainfall and temperatures are now forecast, but it is very doubtful whether this would serve the same purpose as an evaporation record obtained in each locality and subject to local influences.

To close what must be a merely tentative discussion of the evaporation factor as related to forest fire hazards, it may be said:

The records of evaporation obtained at six points during the season of 1923 indicate clearly the character of the variations at any single point and between stations in the same general region. They suggest that the evaporation record comprises a simple means for integrating all of the factors which accompany the periodic changes in barometric pressure, and that this record may have a quantitative value greater than that of any single factor commonly recorded at weather stations—possibly, in relation to fire hazard, greater than any combination of weather elements that might be integrated by computation. It is indicated that evaporation varies so greatly from one point to another near-by point for any single day that to be practically useful to a forest supervisor the evaporation record must be of a local character. It will, possibly, be found later that records obtained in the headquarters towns are not so valuable as those which may be obtained within the forested area.

At least for the present, the absolute evaporation rate can not be considered so important a factor in the fire hazard as the general shape of the evaporation curve. The starting point for all calculations is, apparently, the time when the evaporation rate approaches zero, indicating at least a saturated atmosphere and presumably a well-moistened condition of the forest floor. Because of the importance of this zero point, still further effort should be made to improve the evaporimeter along the line of eliminating all intake of rain water.

TRANSPIRATION BY FOREST TREES.

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HÖHNEL'S EXPERIMENTS.

Aside from scattered data of transpiration from cut branches and meager potometer experiments by Risler, Vogel, Hartig, and Pfaff,[1] few data are available relative to the actual transpiration rate from trees, except the experiments of Franz von Höhnel.[2]

Although published more than 40 years ago, Höhnel's results have not been presented in English otherwise than in brief abstract form. The originals contain numerous misprints, and the results have sometimes been misinterpreted and unjustified conclusions drawn therefrom. It has appeared, therefore, worth while to give these important experiments some further critical study, and present the main results in some detail in English units. Errors and misprints in the originals have been corrected, in so far as possible.

Höhnel's experiments, carried out in connection with the Austrian Forest Service in the years 1878 to 1880, give the transpiration losses and water requirement ratios for a large number of species and varieties of trees. Seedling plants 5 to 6 years old were transplanted to potometers and allowed to stand for three or four weeks to permit the earth to settle. The potometers were 7.8 to 8.2 inches in diameter and 7.5 inches high. Each contained 7.7 to 11 pounds of soil. Conical covers were used to shut out rain, openings being left for the plant stems and for watering through a cork-inserted tube.

In 1878, 44 potometers were used, 24 being exposed in the sun and 20 in the shade. Those in the shade received sunlight from 7 to 9 a. m. and 5 to 7 p. m. For the subsequent years the total number was increased to 79, of which 39 were in the sun, 29 in half shade, and 11 in the shade. The quantity of water transpired was obtained by daily weighings. Meteorological observations were taken three times daily, including temperatures in sheltered, open, and shaded locations, and rainfall and evaporation readings. For each plant the dates of leafing and defoliation were recorded, and at the end of the season the leaf crop was air-dried and weighed and the result recorded. The mean results for 1879 for each variety of tree are given in Table 1. This shows the average transpiration loss in grams from each variety of tree, and also the water requirement ratio expressed in terms of water transpired per unit of dry leaf matter produced.

The water requirement for the year as shown in Table 1 is not always precisely equal to the sum of the water requirement for the summer and winter seasons, as given in the same table. This results from the fact that the experimental data covered the period March 1, 1879, to March 1, 1880, so that in order to obtain the transpiration loss for the period November, 1879, to April 1, 1880, inclusive, the month of March, 1879, was assumed and used to represent the month of March, 1880.

In Table 2 are given the mean water requirements for the same tree in different exposures as determined in 1879. It appears that in general the water requirement ratio for broad-leaved deciduous trees in the sun is about two-thirds that for the same variety in the shade. This result would be expected, since in general any condition unfavorable to plant development increases the water requirement ratio. Actually, the quantity of water transpired from shaded plants averaged considerably more than those in the sun, as shown in Table 3. The difference in the average is mainly due to the excessive transpiration in shade by larch and Scotch pine. Out of 15 kinds of trees for which the comparison is available, 8 transpired more and 7 less in shade than in sun, the excess either way probably depending to some extent on the tree, whether it is to be classed ecologically as sun or shade loving.

[1] Forest influences. *Bull. 7, U. S. D. A.*, 1893, pp. 78-81.

[2] Höhnel, Franz R.: Water requirements of forest trees. (Ger.) *Forsch. Beg. Agrikultur Physik*, 1879, vol. 2, pp. 397-421.

Quantity of transpiration from forest growth. (Ger.) *Mitt. Forst. Veruschwesen Oesterreichs*, 1881, vol. 2, pp. 47, 90, and 287-296.

Water requirement of forest trees with reference to meteorological factors. (Ger.) *Forsch. Beg. Agrikultur Physik*, 1881, vol. 4, pp. 435-445.

The water requirements of forests. (Ger.) *Central Blatt Gesamte Forstwesen*, 1884, vol. 10, pp. 387-409.